

VISIT...

LANZAROTE
Caliente.COM

Positron emission tomography in cochlear implant and auditory brainstem implant recipients

Richard T. Miyamoto*, Donald Wong

*Department of Otolaryngology HNS 702, School of Medicine, Indiana University,
702 Barnhill Drive, Suite 0860, Indianapolis, IN 46202-5230, USA*

Received 4 May 2001; received in revised form 25 June 2001; accepted 25 June 2001

Abstract

Positron emission tomography (PET) imaging was used to evaluate the brain's response to auditory stimulation, including speech. Five cases of adults illustrate the utility of PET to illuminate auditory processing with cochlear or brainstem implants. Subjects showed varying degrees of success in processing speech, which was reflected in the resulting PET images. Functional speech processing was associated with activation in areas classically associated with speech processing. In one patient who did not achieve functional speech processing, activation in frontal regions suggests that the subject used other cognitive strategies to assist auditory processing.

Learning outcomes: As a result of this activity, the participant will be introduced to the principles of PET and the application of this technology to deaf patients who have received an implanted auditory prosthesis. © 2001 Elsevier Science Inc. All rights reserved.

Keywords: PET; Cochlear implants; Brainstem implants

1. Introduction

Positron emission tomography (PET) is an imaging technology that delineates functional neurochemical activity in the brain. PET utilizes radio-

* Corresponding author. Tel.: +1-317-274-3556; fax: +1-317-278-3743.

E-mail address: rmiyamot@iupui.edu (R.T. Miyamoto).

actively labeled probes to explore the functional organization of the intact brain. Positron-emitting isotopes produced by a cyclotron are injected into the blood stream and are concentrated in areas of the body where metabolic activity is high. The PET devices detect the patterns of photon emission for the target organ.

A number of cortical regions, in addition to the primary auditory cortex, are activated by speech stimuli in normal-hearing subjects. Acoustical analysis also occurs in the immediate auditory association cortex and the stimulus is relayed to the lexicon areas of the brain. Bilateral activation has been demonstrated by PET studies.

We have applied PET technology to determine if similar networks are activated in profoundly deaf patients who use multichannel cochlear implants (CIs) or an auditory brainstem implant (ABI). It is hoped that new information regarding neuronal plasticity will also emerge from studies of this nature.

2. Methods

2.1. Patients

Five normal-hearing adults, five postlingually deafened adult CI patients who achieve open speech understanding, one prelingually deafened adult CI patient, and one ABI patient served as subjects.

2.2. PET scanning procedure

PET studies were performed using a Siemens 951/31R scanner, which measures 31 image planes simultaneously over an axial field-of-view of 10.8 cm. The intrinsic image resolution of this system is approximately 6.0 mm full width at half maximum in plane and 5.0 mm in the axial direction.

The subjects were blindfolded during each scan when acoustic stimuli (70–75 dB SPL) were presented monaurally to the right ear in the normal hearing subjects or the implanted ear in the CI subjects. Stimuli were delivered to the right ear of the normal-hearing subjects through an earphone with the contralateral ear occluded with a foam earplug. Stimuli were delivered from a loudspeaker to the microphone of CI subjects listening with their speech processor turned on.

PET scanning was carried out using discrete stimulus conditions, with each condition repeated up to a total of eight scanning periods. Repetition of stimulus conditions permits averaging data within subjects. In each PET session, the first scan was obtained with no acoustic stimulation. This silence (baseline) condition was subtracted from all acoustic-stimulus conditions. The following sequence of acoustic-stimulus conditions were used: broadband noise, multitalker babble,

words from the multisyllabic lexical neighborhood test (MLNT), and the common phrases test.

Fifteen seconds after beginning each stimulation task, 50 mCi of H_2^{15}O was injected intravenously as a bolus, and the tomographic image acquisition was begun concurrently with bolus injection and continued for 3.5 min. A rapid sequence of scans was performed over the 3.5-min interval to enable the selection of a 90-s time window beginning 35–40 s after the bolus arrived in the brain. The subject continued the task for an additional 15 s following the end of the PET data acquisition. The time between the scanning periods was approximately 12 min to allow for radioactive decay to less than 2% of the administered levels.

The identification of regions of significant brain activation were identified using a four-step process, which included (1) image registration, (2) global normalization of the image volume data, (3) identification of the intercommisural (AC–PC) line on either the MRI data or on an intrasubject averaged PET image set for stereotaxic transformation and alignment, and (4) averaging of subtraction images across subjects and statistical testing for identification of brain regions demonstrating task-specific significant changes in blood flow. For data interpretation, a peak analysis based upon the t statistic is performed using a pooled variance derived from the image data.

Images for each condition were averaged across all subjects in the same group, and analyzed using the image subtraction method. Regions of statistically significant increases in activation were mapped in Talairach stereotaxic coordinates. The image-analysis software displays the distribution pattern of activated regions for a subject group after filter smoothing by at 10 mm. The centroids of peak activity have a spatial resolution of 1–2 mm.

To spatially align the PET and MRI images, standard anatomic MRI images were segmented to identify gray matter, white matter, and CSF. Pixel intensity values were set in each of the segmented regions to expected PET radionuclide levels for each tissue type and the data smoothed to the same resolution as the PET data. The image volumes are then registered as rigid bodies (three translation parameters, three rotation parameters, and one scale parameter) using Newton's method based on a least squares cost function. The registration parameters derived from this algorithm were then applied to the original MRI image data in order to map the PET results onto the anatomical images.

3. Results

Despite the nonphysiologic speech coding strategies used by current CI systems, postlingually deaf CI recipients appear to process speech sounds in an analogous manner to normal-hearing subjects. Stimuli perceived as speech by both normal and CI subjects evoked strong bilateral activation in the superior

temporal gyri, which are regions that include the primary and secondary auditory cortices. Similar auditory cortical areas are stimulated by speech and speech-like stimuli in postlingually deaf patients who have received a multi-channel CI as in normal-hearing subjects. Similar observations were made in a subject who uses an ABI. Broadband noise did not significantly activate the auditory cortex.

The prelingually deafened adult CI recipient who had communicated in ASL during his early language acquisition years did not achieve open speech understanding with his CI. An initial PET scan taken 2 months after switch-on revealed activation only in the basal frontal cortex in speech tasks. Two years after initial stimulation right frontal cortical activation was observed near a region homologous to Broca's area in sentence tasks.

4. Discussion

Complex speech is initially processed by undergoing acoustical analysis in the primary auditory area and in the immediate auditory association cortex and is then relayed to the lexicon areas of the brain to be matched with encoded entries for familiar words. Bilateral activation of extensive areas of both the primary auditory area and the immediate auditory association area has been documented.

Although the ABI patient does not demonstrate open speech understanding abilities, activation of the auditory cortical regions was shown. This suggests that he not only processes speech and nonspeech signals in a similar manner to normal-hearing subjects but is also capable of accomplishing this with minimal acoustic information.

The absence of activation of the auditory cortex in a prelingually deaf adult who has previously communicated only with sign language after 22 months of CI use is consistent with clinical observations. The activation of the right frontal cortex is felt to relate to short-term memory retention of pitch information and suprasegmental aspects of speech. Activated motor subcortical regions may be related to subvocal articulatory processing while attempting to perform language tasks. Should this subject acquire open speech skills in the future PET activation will be repeated to determine if activation in the classical language centers occurs.

Appendix A. Continuing education

1. PET produces images
 - a. by using radioactively labeled isotopes
 - b. by capitalizing on the body's magnetic properties
 - c. by tracking a contrast agent in the brain

- d. by measuring the brain's electrical activity
 - e. none of the above
2. In this study, all subjects
- a. performed equivalently to normal hearing subjects
 - b. failed to demonstrate functional hearing
 - c. failed to evidence auditory processing
 - d. had variable success with implanted devices
 - e. showed consistent areas of activation in response to auditory information
3. In order to assess auditory processing with PET
- a. auditory stimulation conditions were subtracted from a baseline of silence
 - b. several forms of auditory stimulation were used
 - c. functional images were coregistered with a structural image to pinpoint anatomical regions of activation in auditory cortex
 - d. stimuli were repeated multiple times to produce an average
 - e. all of the above
4. When stimuli were perceived as speech by implant users
- a. all processing was done at the level of the brainstem
 - b. nonauditory cortical regions were primarily active
 - c. auditory cortical regions were primarily active
 - d. activations associated with speech were distinct from those associated with speech-like sounds
 - e. activations association with all auditory stimuli were no different than baseline
5. In the subjects studied
- a. CIs made no functional difference in hearing status
 - b. CI use resulted in hearing without demonstrable cortical activity
 - c. brainstem implantation resulted in superior cortical activation relative to cochlear implantation
 - d. variation in hearing outcome was associated with variation in cortical activation to speech stimuli
 - e. Nonauditory regions were recruited to support hearing after implantation.

Recommended readings

- Ito, J., Sakakibara, J., Honjo, I., Iwasaki, Y., & Yonekura, Y. (1990). Positron emission tomographic study in a patient with a cochlear implant. *Archives of Otolaryngology, Head & Neck Surgery*, 116, 1437–1439.
- Miyamoto, R. T., Wong, D., Pisoni, D. B., Hutchins, G., Sehgal, M., & Fain, R. (1999). Positron emission tomography in cochlear implant and auditory brain stem implant recipients. *American Journal of Otology*, 20, 596–601.

- Naito, Y., Okazawa, H., Honjo, I., et al. (1995). Cortical activation with sound stimulation in cochlear implant users demonstrated by Positron Emission Tomography. *Cognitive Brain Research*, 2, 207–214.
- Naito, Y., Okazawa, H., Honjo, I., et al. (1995). Cortical activation during sound stimulation in cochlear implant users demonstrated by Positron Emission Tomography. *Annals of Otology Rhinology and Laryngology*, 104 (Suppl. 166), 60–64.
- Wong, D., Miyamoto, R. T., Pisoni, D. B., Hutchins, G., & Sehgal, M. (1999). PET imaging of cochlear-implant and normal-hearing subjects listening to speech and nonspeech. *Hearing Research*, 132, 34–42.